

The Direct Fixation Fastener—Its Past and Its Future in Rapid Transit

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When compared to most other trackwork components, direct fixation fasteners are relatively new products in transit applications at North American transit authorities. In the past, some difficulties have been experienced by procuring operators as well as fastener suppliers in specification compliance and effective part design. With the introduction of newer, more technically advanced direct fixation fasteners at various authorities, a reevaluation of the older style of specifications and testing procedures is necessary to avoid past difficulties and provide a more effective qualified product to the authorities. Past procurement practices and proceedings in general are reviewed with suggestions for possible improvements to balance trackwork and the vibrational requirements in specifications for direct fixation fasteners.

Within rail transit there has been constant and continuing misuse of the phrase direct fixation fasteners (DFFs). On some occasions it has come to mean everything from flexible clips, clip and shoulder assemblies, to clips on thick rubber and steel assemblies. Rather than attempting to correct any inherent misuse of the term by manufacturers, consultants, and authorities, it is simpler to identify what most trackwork personnel have come to understand as a direct fixation fastener.

The direct fixation fastener is a system composed of clips with a thick elastomer and steel body unit that holds the rail to tie or concrete slab, provides electrical isolation, and has an additional function of providing major vibration, shock, and noise reduction to the track-car system as a whole. It was conceived and designed for use in a rapid transit system for these purposes. It is this type of multifunctional direct fixation fastener system that is discussed in this paper (Figure 1).

The major point of the DFF that sets it apart from the standard steel tie plate is that one of its primary functions is maximum vibration, shock, and noise control for the entire track-train system. This is accomplished through the use of elastomeric elements acting as a spring-mass system between the rail flange and the support base. Studies have shown that fasteners with stiffnesses in the range of 50,000 to 120,000 lb/in. are required to reduce vibration in the critical frequency ranges of 10 to 100 Hz.

In discussing direct fixation fasteners, a second major point must be considered: the fastener system must function as an integral part of the total trackwork system. Vibration and trackwork requirements can be made compatible in order to provide the best advantages to both areas. There is no conflict between the vibration and the trackwork requirements for DFFs if the specifications allow the fastener designer to use existing proven design concepts.

In the past, difficulties in fastener procurement have usually been caused by a lack of understanding of the intent of various specific tests within the specifications, which created inherent conflicts between vibration and the trackwork concepts. Although realistically it is impossible to write a perfect specification, especially for what has now become a multifunctional part, far fewer problems will be encountered when basic fastener concept requirements are better understood. To better understand fastener concept requirements, how they are viewed by transit authorities must first be determined.

The usual authority requirements for DFFs include

1. Low life-cycle cost and reduced fastener maintenance.
2. Improved passenger and wayside comfort.
3. Maintenance of a high fastener reliability level for maximum operational state of the total system.
4. Maximum electrical isolation for maintaining signal strength and reducing stray current.
5. Reduced maintenance of other trackwork components and train subsystems.

Although these requirements are general and would be satisfactory to any authority, their implementation into a procurement document requires a series of steps.

The first and one of the most vital steps is in the procurement of the DFFs. The three types of procurement processes have been described by Hanna (*1*) and of these the two-step process is the most effective in obtaining a low life-cycle cost fastener. It has been the one-step or low-bid type of procurement that in the past has resulted in poor quality fasteners and design submissions and subsequent procurements not intended by the specification writer.

In contrast, the reviews and prequalification within a two-step process, however, provide ample framework for eliminating suppliers that do not meet or conform to the criteria and intent of the specifications. The only further improvement that should be made in the two-step process is that all suppliers should be required to test at a single independent laboratory. This will eliminate the wide-ranging results now being received from different laboratories using different test equipment and methodology. As it now stands, it is impossible to directly compare results received from direct fixation fasteners tested at different laboratories to make any valid sole source prequalified procurement. In summary, true low life-cycle costs can only be achieved when sufficient time is allowed for all the necessary procurement steps, specifications written for a specific type of fastener, and valid laboratory comparative testing available in a two-step procurement process.

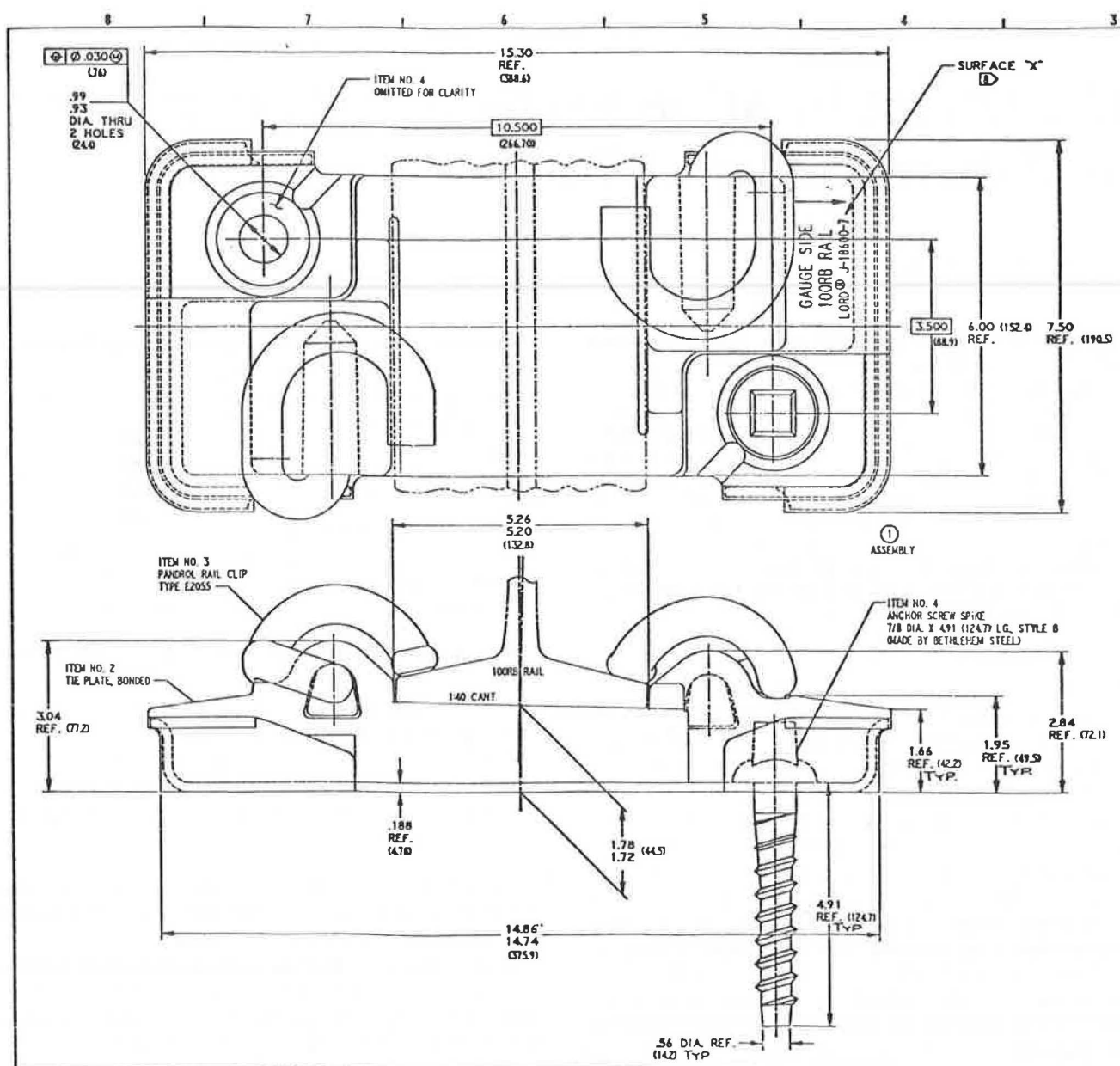


FIGURE 1 Typical direct fixation fastener.

Underlying all of the procedural efforts in fastener procurement is the fact that any DFF system installed will have to be inspected and maintained over its estimated life of 30 to 50 years. A number of authorities have direct fixation fasteners that will now require excessive hours of maintenance in order to conform to normal accepted trackwork standards. Although the reasons are varied, they can in most cases be traced to the procurement document itself. Any low first cost for DFFs will be overshadowed by constant and significant maintenance expenditures.

In this time of withdrawal of federal support for operating expenses, it is obvious that a low first cost for a fastener that has a high life-cycle cost will have a severe financial effect on an authority in the future. It should be noted that within the formation of any new authority, possible input from the maintenance group on design features may be limited because of lack of personnel at the time of the DFF procurement. In this case

the responsibility must rest with the consultant and other authority groups to anticipate inherent maintenance requirements and subsequent maintenance costs within any submitted design.

Although a low first cost does not necessarily indicate a high life-cycle cost, it must be recognized that once a bid is opened, within the review of the low bid submission, the proposed DFF must have a significant design defect to be rejected. Because the value of a significant design defect is subjective, and the possibility of design correction is also open to subjective evaluation, the reviewer can be subject to both professional and legal difficulties with a negative decision on the submission of the low bidder. Recognizing these complications, some DFF suppliers will submit a low-cost design below specification, knowing that an initial rejection usually does not occur, and by delaying the furnishing of fasteners, exceptions and deviations to the technical specifications must be granted to ensure the

system is built on schedule. The solution to this problem again goes back to the two-step procurement system.

The improvement of passenger and wayside-occupant comfort by reducing the effects of vibration and noise, at first glance, appears to be a minor point and something that must be tolerated by an authority. Nothing is further from the truth. Attendance at a community interface group meeting when a new system is being proposed will provide insight into the real concerns—noise and vibration. On a new system, substantially more time, money, and effort are expended trying to overcome the impression that all rapid transit systems are noisy than are actually extended on direct fixation fasteners. Given the inputs constantly received by actual ridership, movies, and TV as to what the old transit systems sound like, it is understandable why everyone wants a transit system as long as it does not run next to their house (Figure 2). On existing systems, any expansion of the present system into new areas is faced with the same problem of community acceptance as any new system. The wayside occupant and onboard passenger on older systems show a significant decrease in their tolerance and acceptance of noise and vibration. The direct fixation fastener's ability to retrofit older existing trackwork systems is now being used by some authorities.

It must be noted that the DFF system affects the noise and vibration levels experienced not only by the wayside occupant but also the onboard passenger and thereby serves a dual function. This is a critical point especially where any system is confined at grade by buildings or is below grade in tunnels where the wayside occupant and the onboard passenger are subjected to radiated and reradiated noise. Again, one of the major reasons for direct fixation fasteners is vibration and noise reduction working within all of the various aspects of the trackwork system.

In maintaining high levels of system operations and availability, there are many short- and long-term considerations. In the short term, the specifications must provide that the fastener quality and design integrity are sufficient to meet system needs

without premature replacement. Given that all authorities have only a limited window of availability for track repair, any substantial change-out requirement because of fastener problems can become not only costly but a logistical nightmare for an authority once the system becomes operational. It is not reasonable to expect the DFF supplier to guarantee the fasteners for extended periods of time without total knowledge of maximum trackwork load system factors. It is reasonable to expect guarantees from manufacturers as to the workmanship and quality of production manufacturing even if the specification also requires production testing. It is actually the consultant and the authority working through proper specification and testing that will ensure that the fastener system maintain ongoing operational levels and track availability.

In the long term it is generally recognized that slab track in combination with DFFs is a low life-cycle arrangement. Some of this revolves around the point that the DFF in most recent configurations requires little or no maintenance. Compared to ballasted track, which will require ongoing maintenance with work crews and specialized equipment, two DFFs can be changed out by one man with a torque wrench and jack in a matter of a few minutes. When the long-term factor of ballast cleaning or significant quantities of tie replacements are considered, the operational service levels of the future system operation could be interrupted in a significant way.

When the electrical requirements placed on direct fixation fasteners are examined, are the multifunctional aspects to which it must perform understood? Although not all systems use track for signal circuits, the problem of stray current control appears to be more prevalent. Because authorities differ on their requirements, tests and testing criteria vary greatly. Recently, authorities have been viewing electrical surface tracking and air gap between charged and ground potential portions of the fastener with greater interest. The present difficulty occurs because within the specified dc and ac testings, no uniform method has been formulated that can be performed in a laboratory to duplicate contaminant build-up on the DFF. Wheel and

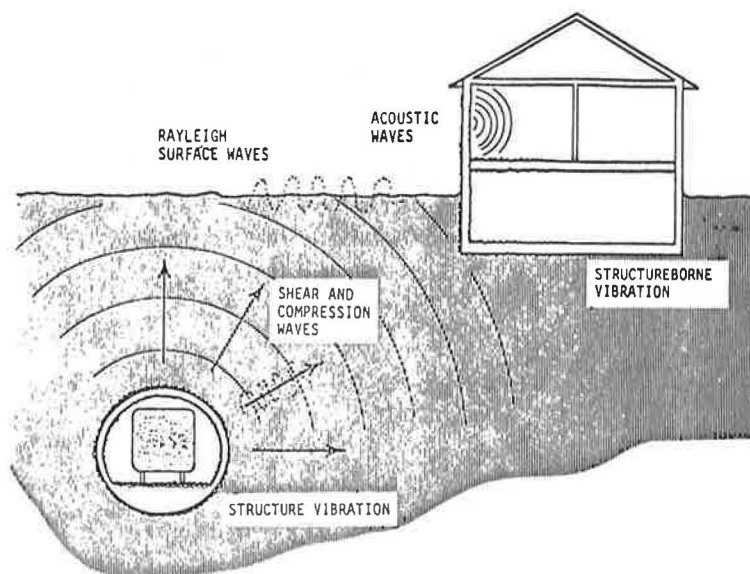


FIGURE 2 Example of vibration propagation.

rail metallic particles and other environmental contaminants on the fasteners can cause significant signal loss and stray current and, without some uniform testing method, subjective evaluation of the fastener design must continue to be relied on. It should be noted that bonded fastener designs are far less prone to tracking because of significantly longer surface paths and elimination of particle trapping design voids.

One of the benefits of soft direct fixation fasteners that has been totally overlooked is the possibility of reduced track and train design costs. The fastener system inherently changes the train-track system by providing a compliant support system that reduces shock and vibration inputs to the car, its equipment, and passengers. To date this author is not aware of any change to equipment specifications that recognizes this reduction in shock and vibration input and the subsequent possible cost reductions as a result of changes in car equipment design. Also, looking below the fastener base, this author is also unaware of any design reduction in track support systems that might be caused by reduced shock loading or lower vibrational levels going to any of the various types of structures involved. A review of track-train dynamics as they apply to direct fixation fastener track could possibly bring significant cost reductions to track and train design.

The design decision requirements and procedural processes necessary for effective DFF procurement have been discussed in broad terms. Underlying and supporting this process is the basic specification and testing document, which will ultimately determine the design of the fastener, its operating characteris-

tics from both the trackwork and vibrational standpoints, maintenance requirements, life expectancy, and cost. When the basic requirements of a standard steel tie plate in trackwork is compared with the multifunctional requirements of a DFF in rapid transit trackwork, it is easy to understand why two-step procurement with a good specification foundation is an absolute necessity.

Although direct fixation fasteners have been in use for some time, basically only one general specification has been used by most authorities (Figure 3). With the exception of the vertical load test and the dynamic-to-static test requirements, the major point of fastener vibration requirements went unrecognized within the specification, which dealt almost exclusively with the trackwork requirements for fasteners.

As with any new product used in trackwork that must be proven safe and effective, it was understandable that this would be of greatest concern during the early period. There has never been any reported accident or derailment attributed to DFFs; therefore, it can be assumed that the trackwork requirements of the specifications for safety have performed well. However, this does not preclude the possibility of DFF failure in the future because of poor basic design. It should also be understood that bonded fastener designs are not totally dependent on their metallic components to maintain trackwork integrity but have an additional safety feature of the elastomeric bonding. As observed at one authority, failed metallic components of fasteners did not result in catastrophic gauge widening because of the restraint provided by the fastener bonding feature.

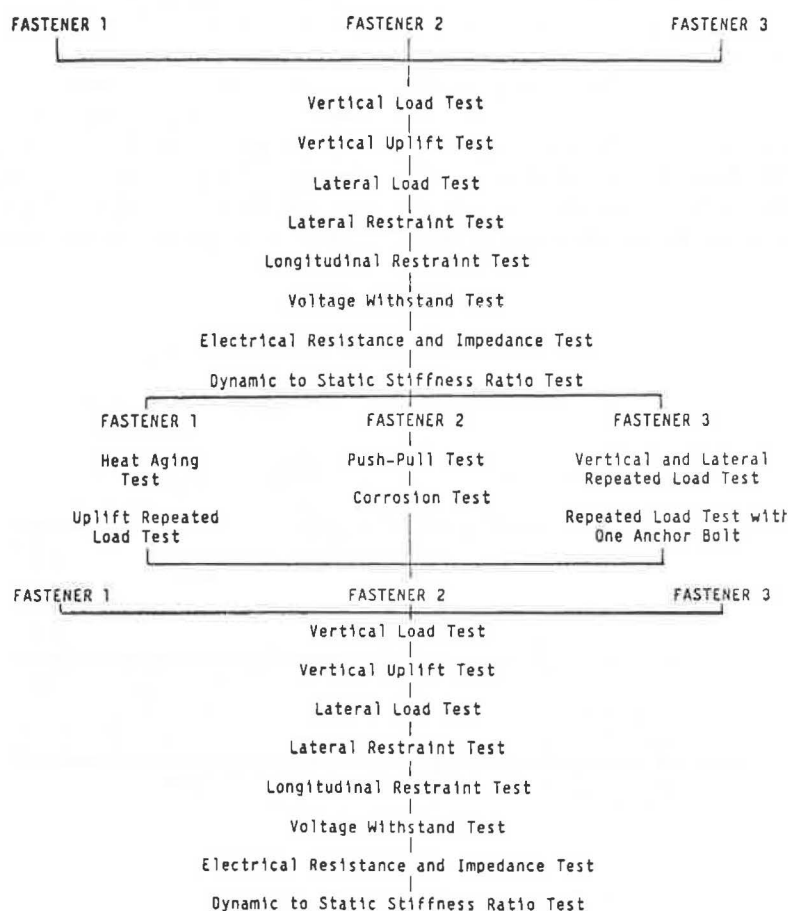


FIGURE 3 Fastener test sequence.

With the addition of new authorities in the United States and Canada and the use of this same basic specification as a core document, difficulties arose. Test loadings kept increasing to ensure that successive procurements would result in a stronger and better fastener. Unique design features desired by authorities were placed into specifications with little regard for other testing requirements and overall design impact. The original reasons for the individual tests and the test acceptance criteria results became vague and subject to arbitrary decisions that varied with each authority. The vibrational design portion of the specification and any testing requirements continued to remain low, and there was no recognition of possible new improved designs increasing vibration control and reducing noise, nor could they be proposed or tested under the existing specifications.

Finding the direct fixation fastener industry in a position of having to reassess procurement methods and specifications, a return to wood ties in ballast with cut spikes might be tempting. Thankfully, certain authorities such as the Washington Metropolitan Area Transit Authority (WMATA) have required a new specification core document that begins to recognize a better balance between trackwork and vibrational requirements for direct fixation fasteners. The foundation for this new specification is based on tests performed by the U.S. Department of Transportation Transportation Systems Center (TSC) in actual

trackwork at WMATA (Figure 4). This test basically showed that while improving the vibrational characteristics of DFFs by further softening them both vertically and laterally above what was called for in prior specifications, trackwork characteristics were also improved without excessive gauge widening. The previously perceived track loadings, based on data from stiffer DFFs that were perceived to be valid and then subsequently required in the old test specifications, were not valid. Instead, with soft vertical and lateral fasteners, actual loading on the individual fasteners is greatly reduced. This forms the basis for a new core specification and brings into balance the vibrational and the trackwork requirements (Figures 5 and 6). In addition, the new specification still retains many of the basic prior trackwork testing requirements in order to continue to ensure integrity and safety in trackwork.

Although some would argue that this new type of specification and the data values are site- and authority-specific, it is the concept that is universal and the specific data values that are site-specific. The difficulty of obtaining data values at operational authorities is minimal when compared with improved performance benefits and lowered life-cycle costs to the system. For those authorities still in planning and preconstruction stages, it would be valid to draw data from an operational system with similar car and track configurations for specification data values. To continue with the old specification, which is formed on an incorrect data base, is costly and results in far less than optimum total system performance.

As stated previously, the new specification for soft vertical and lateral fasteners still retains many of the previous tests required for trackwork integrity. It must be noted that these tests also must be reviewed for their overall compatibility with soft vertical and lateral direct fixation fasteners within the specification. In the old testing specifications, some tests such as the lateral load or lateral restraint test, or both, were performed to ensure that excessive gauge widening did not occur during operation. Although the testing intent from the trackwork standpoint was valid, it resulted in manufacturers' stiffening the fastener designs laterally. This stiffening, in almost all cases, also resulted in a design with a vibrational short circuit laterally in the anchorage area, causing subsequent loss of maximum vibration isolation, which was contrarily the basic reason for the DFF application.

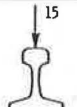
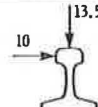
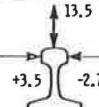
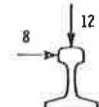
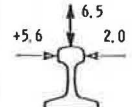
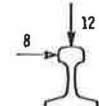
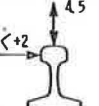
	VERTICAL LOAD (KIPS)	LATERAL LOAD (KIPS)	REPEATED LOADS (KIPS)
WMATA TW-8			
MEASURED VALUES 755' CURVES			
RED LINE			

FIGURE 4 Comparison of WMATA fastener acceptance specifications and measured values.

		SPRING RATE AND DEFLECTION TEST			REPEATED LOAD TEST				
		CASE							
		1	2		3	4	5		
VERTICAL CURVE V	A	-870	-520		-1044	-1298	-862	LBS	TOTAL RESPONSE LOAD
	B	+20	+12		+24	+30	+20	KIPS	
	C	+13	+7.8		+15.6	+19.5	+13.1	KIPS	
LATERAL CURVE L	D	-340	-510		-408	-850	-850	LBS	
	E	+8	+12		+9.6	+20	+20	KIPS	
	F	+3.1	+4.7		+3.7	+7.8	+7.8	KIPS	
NO. OF CYCLES OF EACH CASE PER 100 CYCLES OF REPEATED LOAD TEST.					98	1	1		

FIGURE 5 Test load values.

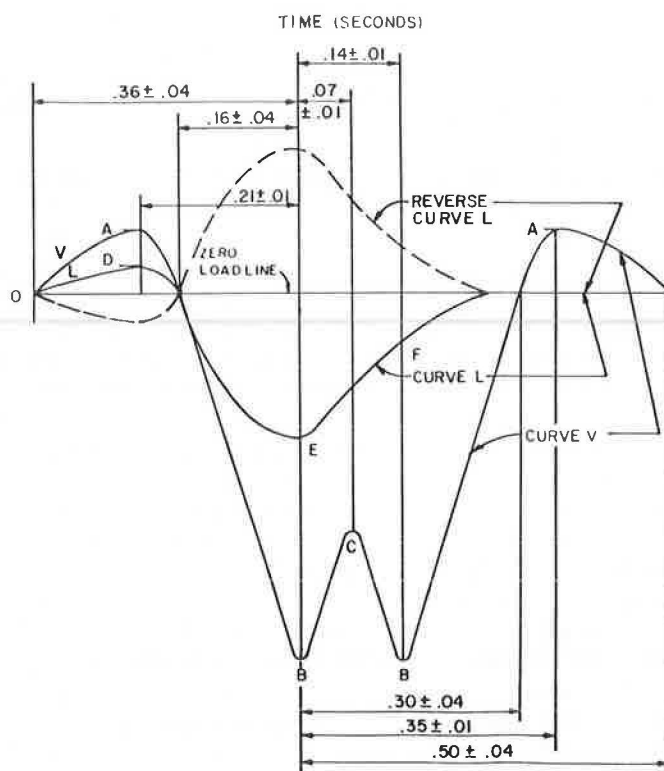


FIGURE 6 Test load sequence.

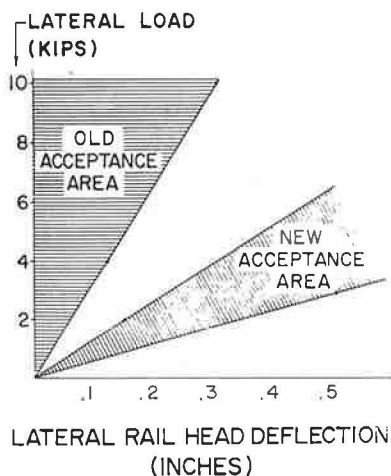


FIGURE 7 New versus old lateral static load acceptance criteria.

On review of the TSC/WMATA in-track testing of soft lateral fasteners with greater load distribution over greater numbers of fasteners, rail head motion and gauge, when loaded to the values that occur with this type of DFF application, remains within acceptable trackwork standards. Relating this to specifications, old data high load tests taken from stiffer fastener measurements with limiting motion acceptance criteria are not needed; what is needed are controlled maximum lateral stiffness requirements taken from in-track soft fasteners to allow greater load distribution patterns within the trackwork system (Figure 7). With this type of system, the necessary trackwork integrity is maintained while the vibrational reduction achieved from the DFFs is greatly improved.

It is also necessary to point out that the soft vertical and lateral fasteners in almost all cases require a somewhat larger space envelope for elastomeric materials in order to provide the necessary fatigue properties. Design of direct fixation fasteners is complex with many interdependent criteria that are partly predetermined by the technical and testing portions of the specifications. There is no problem in obtaining comparable fatigue life for soft versus stiff direct fixation fasteners if the specifications allow the necessary parameters.

A general review must be conducted of all of the static tests when moving to the new testing specification required of the soft vertical and lateral DFFs. It is reasonable that any authority or its designated consultant can work with the suppliers as a whole to accomplish such specification reviews. Although this has been done in the past, it normally occurred after the specifications were prepared. What is specifically needed now is this total interface among the parties before preparation of the specification document.

One level below the specification and tests required are the test laboratory and equipment. There exists an anomaly within all fastener test equipment in that few, if any, laboratories can duplicate actual in-track conditions and loadings. The size of test equipment and associated massive costs to set up and duplicate exact track operation and loads would be exorbitant in relationship to the information derived for fastener procurement. Also, it would probably stop all improvements to existing designs and end all new design efforts at the manufacturers because of the excessive cost. It would appear that a group of four fasteners is the maximum practical testing limit capability, recognizing that this only approximates in-track rail load distribution conditions to the fasteners (Figure 8). It then

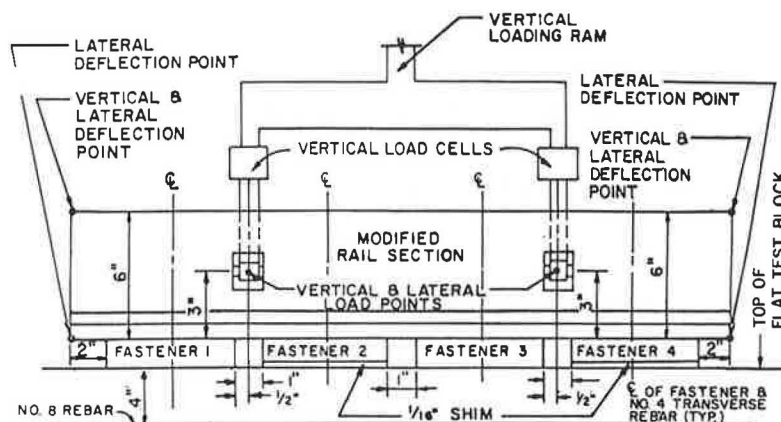


FIGURE 8 Machine setup for fastener test.

follows that data received from certain tests will only give approximate values for evaluation and should be recognized as such. Far too often, specification test data from laboratory testing were erroneously assumed to simulate what would actually occur under actual track conditions. Many of these tests were only intended to show relative performance of various DFFs from different supplier sources and different designs. An example of such tests having relative data would be the dynamic-to-static test required in many specifications. The number generated by this test is material dependent and should only serve as a relative guide for the efficiency of the elastomeric material in its vibration-reduction function. The resultant can be stated within the specification in a maximum number format for elastomeric material acceptance criteria; however, other factors such as plate masses, elastomer thickness, and design features may have more bearing on the final performance efficiency of the DFF in overall vibration reduction.

CONCLUDING REMARKS

It might be concluded from the preceding discussion that procurement of direct fixation fasteners is difficult to

accomplish. Although this has been true in certain cases in the past, the growing knowledge of DFFs and their requirements continues to increase in the transit community. The direct fixation fastener with its multifunctional role in the rapid transit trackwork system and specifically the newer soft vertical and lateral DFFs simply requires more time in the preprocurement stages. The strength of rapid transit systems depends on the continuing improvement of existing products and methods and the continuing introduction of new concepts. Funding pressures now more than ever demand cost-effective improvements if North America is to remain in the forefront of technical leadership.

REFERENCE

1. A. N. Hanna. Procurement and Selection of Direct Fixation Fasteners for Transit Projects. In *Transportation Research Record 1071*, TRB, National Research Council, Washington, D.C., 1986, pp. 1-6.

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